§28. Study of Heavy-metal-ion-beam Production with Tandem Accelerator for LHD-HIBP System

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The heavy ion beam probe (HIBP) is one of a method of plasma diagnostics, which can measure the potential profiles in plasma. An HIBP system has been installed at the Large Helical Device (LHD-HIBP) [1]. In recent HIBP diagnostics, the current of the heavy ion beam is sufficient for the electron density of 10^{19} m^{-3}. Since the attenuation of the probe beam is severe in higher density plasma, larger Au^+ current is necessary. Some studies investigating how to increase the current have been done [2, 3]. These objectives are to increase the negative ion beam current and to improve the charge exchange efficiency in the gas cell of the tandem accelerator, the beam transport efficiency, and the detection efficiency of ejected ions and so on. Especially, the experimental study to optimize the gas cell for high charge exchange efficiency is not easy using LHD-HIBP because it takes much time to change gas species in the gas cell. We have studied on the subject using a tandem accelerator at Kobe University [3]. The accelerator has a gas cell, and the terminal voltage is up to 1.7 MV. In this fiscal year, the charge fractions of Au beam generated by the tandem accelerator were measured, and some ionization cross sections for Au ions or neutral atom were obtained.

To obtain the charge fraction, measurements of the ion current are necessary. The current can be measured with a Faraday cup (FC). Since the initial state of the ion is negative in the present work, measurement of neutral atom is also necessary. We consider the use of MCP because the *initial* secondary-electrons can be produced by ions or neutral particles at the entrance section of the MCP. Two stages micro channel plate (Hamamatsu photonics Inc.) was used and set on *x*-*y* movable stage. Entrance of MCP was biased at 1800 V, and exit was biased at 300 V. The collector has ground potential. The current detected by MCP have been calibrated with an error up to several tens percent [4].

Because a gold ion has a large mass, the velocity is small. Therefore, the beam becomes broad by a space charge effect. To obtain accurate cross sections, it is necessary to measure the beam shape. The shapes for neutral beam, positive beams were measured with movable MCP. For example, the dependence of FWHM of the neutral beam profile in *x* direction on Ar target thickness is shown in Fig. 1. The incident energy indicates the ion's energy at the entrance of a gas cell. In this case, the energy is the same as a neutral ions entered to MCP. These FWHM become large as the incident energy and the gas thickness are large. The FWHM dependences in *y* direction were also measured. The values were almost same as that in *x* direction. The FWHM dependences for positive ion beams in *x* and *y* direction were also measured.

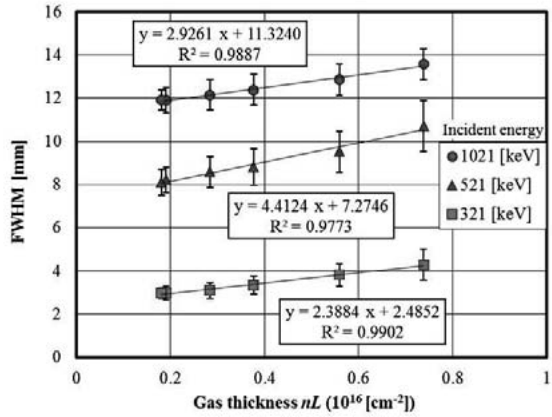

Fig. 1. Dependences of FWHM of the neutral beam profile in *x* direction on the Ar gas thickness.

The aperture was installed at the entrance of the MCP. Because of a part of the beam entered to MCP, the current of the beam must be integrated over the beam profiles obtained above experiments. The dependences of the currents for each beams, i.e. the charge fractions, on gas thickness are shown in Fig. 2. In this experiment, the terminal voltage is 500 kV, and target gas in a cell is Ar. Some ionization cross sections were obtained from the results, $\sigma_{-1,0} = 4.3 \pm 1.3$, $\sigma_{-1,1} = 1.0 \pm 0.4$, and $\sigma_{-1,2} = 0.62 \pm 0.15$. Fitting curves were calculated with the rate equations. Those cross sections obtained in the experiment were used for solving the equations, and other cross sections estimated by the methods described in Ref. [2].

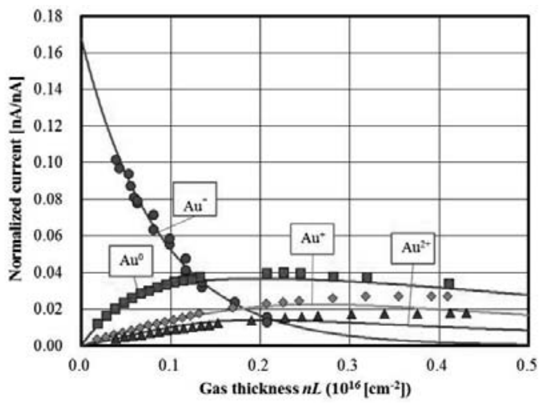

Fig. 2. Fractions of Au beams for Ar target as a function of gas thickness. The terminal voltage is 500 [kV].

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[2] M. Nishiura *et al.*, Rev. Sci. Instrum. **79** (2008) 02C713. 675-678.
[3] A. Taniike *et al.*, Plasma Fusion Res. 5, S2087 (2010).
[4] A. Taniike *et al.*, Plasma Fusion Res. 8, 2401087 (2013).